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Teaching integrated system design with interdisciplinary group design exercises.

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Abstract

With funding from the UK's Royal Academy of Engineering, the University of Edinburgh has developed a set of three truly interdisciplinary group design exercises aimed at improving penultimate-year undergraduate students' ability to operate across disciplines and improve their preparation for transfer into industry. Three exercises on: hydropower system design; potable water supply; and a micro-system accelerometer, are each designed and led by a Visiting Industrial Professor. They are both challenging and popular with students and have achieved several very successful outcomes: experience of real system design; enhanced appreciation of other engineering disciplines; experience of team working where participants have different skills and expertise; demonstration of the links between design and economic viability; introduction to non-technical areas essential to fulfilling the UK Standard for Professional Engineering Competence, etc.

Keywords

Interdisciplinary design teaching; systems engineering; group design exercises; student experiences and feedback.

File Word Count

6,000 words (note reduction of feedback panels can save words)

1 Introduction

The supply of qualified and skilled engineering graduates is essential for the modern economy. However, a significant number of UK engineering firms report engineering graduate shortages and skills deficiencies in problem solving, application of theory to real problems and inadequate breadth of knowledge (Spinks *et al.* 2006). With less than half of the engineering graduate cohort entering the engineering profession after graduation (Engineering and Technology Board, 2007) there is a need to develop graduates with these enhanced skill sets.

The skills expected from UK undergraduate degree courses are specified by the Engineering Council UK, the body responsible for ‘setting and maintaining realistic and internationally recognised standards of professional competence and ethics ...’ Their standards (UK-SPEC 2008) specify a range of learning competencies: underpinning science and mathematics; engineering analysis and design; the economic, social, and environmental context; and engineering practice (Engineering Council 2008). Many of these requirements are a challenge for universities to teach when they relate much more to practical industrial experience.

The challenges are compounded by the evolving role of graduate engineers. The traditional mono-disciplinary model of engineering assumes graduates will work as specialists (Royal Academy of Engineering 2006). As a result, students identify strongly with their own engineering discipline and are often ignorant (and sometimes dismissive) of other disciplines. However, large employers expect graduates to join multi-functional teams designing complex systems within which graduates of traditional single-discipline degree courses are ill-prepared. Additionally employees within SMEs must cross disciplines by handling and integrating a variety of technologies and techniques (Royal Academy of Engineering 2006).

The preparation of engineering graduates for industrial careers features frequently in industrial and academic literature (Lee and Messerschmitt 1998, Martin *et al.* 2005). In the USA, “Capstone” courses draw together knowledge gained in earlier years and apply it in open-ended ‘real world’ projects (Todd *et al.* 1995, Dutson *et al.* 1997, Todd and Magleby 2005). There is recent evidence that industrial input is attractive to students and possibly attracts higher grades (Mendez 2008). In the UK, the Royal

Academy of Engineering (2006) suggests that undergraduate syllabi can better prepare graduates by promoting “integrated system engineering” within a holistic approach. With this in mind they instigated a ‘Visiting Professors’ (VP) scheme to help universities teach engineering design to undergraduates that relates closely to engineering practice. It finances the involvement of industrialists – the ‘VP’ – in the design, delivery and assessment of specialist course modules. To date, four programmes have been set up in: Principles of Engineering Design (Skates 2003), Engineering Design for Sustainable Development, Integrated System Design and Innovation and Design. The Integrated System Design programme initiated a series of interdisciplinary group design exercises at the University of Edinburgh.

2 Interdisciplinary Design Exercises

Four UK universities took part in the 2005 pilot scheme of the Integrated System Design programme (Royal Academy of Engineering 2006). Following open competition a further six universities joined the scheme in 2006. With each university able to interpret the brief in a different way, VP’s have been tasked with encouraging systems integration principles and interdisciplinary activities, extending existing teaching of systems engineering or providing lectures on fundamental concepts early in the degree programme. Rather than implement a formal course, Edinburgh sought to involve the VP’s in designing realistic interdisciplinary group design exercises, that, due to the involvement of multiple engineering disciplines, were totally different from the conventional single-discipline design projects in many BEng/MEng degree programmes.

The School of Engineering at the University of Edinburgh is a multi-disciplinary budget unit, which readily facilitated involving students from all disciplines. Students take common first year courses before selecting to study one of the four main engineering disciplines (Chemical, Civil, Mechanical and Electrical/Electronics) from their second year onwards. Academic staff within the School are organised thematically by research institute (e.g., Materials and Processes, Integrated Systems, Energy Systems) together with their post doctoral researchers and PhD students and they flexibly deliver teaching across the disciplines. This allows areas like Energy Systems, in which interdisciplinary research is critical, to be configured as a cross-disciplinary, thriving, focussed research institute.

With the honours year headcount being of the order of 250 students it was decided to restrict these group design exercises to the circa 150 students on the MEng programmes. To manage numbers and to cater for students' preferences and the relative popularity of disciplines, three separate design exercises were initially developed. The scope and subject matter aimed to offer opportunities for true interdisciplinarity. This differentiates them from many other interdisciplinary projects mentioned in the literature which mainly involved teaming electrical and electronics engineers with other disciplines: mechatronics (with mechanical engineers, O'Connor *et al.* 2001); sensors (with physics); wearable computers (with computer science; Amon *et al.* 1995); and educational toys (with mechanical, IT and design; Ivins 1997).

We aimed to enable our students to work within such multidisciplinary teams, to soften their perception that boundaries exist between disciplines and to introduce them to the *industrial design* environment. Our fundamental aim was to improve the student awareness of engineering as a whole and the exercises were not intended to influence in any way the student's ultimate career choice. Our group design exercises strongly reflect aspects of the School's research expertise and represent exemplars of complex and interdisciplinary undertakings where we were able to secure an appropriate VP appointment: hydropower, potable water supply and micro-systems. We could have selected other appropriate engineering topics, provided they satisfied our educational goal of introducing interdisciplinary study which applies taught theory to real problems and expands the students overall knowledge. These exercises provide different combinations of disciplinary involvement (Table 1) over a wide range of scales from nanometre-scale in micro-systems, up to kilometres for the other two. The workload and assessment procedures for each exercise are broadly aligned and an element of cross-marking is undertaken to ensure consistency in rewarding students for their achievements in these exercises, compared with their other taught modules (Mendez 2008). A VP together with a local academic team designs and leads each exercise and offers considerable freedom for the VP to introduce challenging design goals. In 2009, a further exercise was introduced on passive house design, for all engineering disciplines, to better address the building services sector and energy consumption issues.

	Discipline			
	Electrical	Mechanical	Civil	Chemical
Hydropower	Yes	Yes	Yes	No
Potable Water Supply	Yes	Yes	Yes	Yes
Microsystems	Yes	Yes	No	Yes

Table 1: Engineering discipline participation matrix in three design exercises

3 Group Design Exercises

3.1 Hydropower system design

The aim here is to develop a well-balanced, feasible, small hydropower system design for Glen Kinglas in western Scotland (Harrison *et al.* 2007). As well as producing a study for presentation for funding, technical aspects have to be fully investigated and calculated before being delivered in the final report. Engineers, Table 1, work in groups of six or seven students and investigate all aspects of the hydropower design. This covers hydrology, civil construction and pipelines, turbine and generator selection, control and auxiliary systems, grid connection as well as environmental impacts. The requirement is that the student designs be as economically viable as possible to reinforce that engineering activity is not independent of the wider market. The key feature of the hydropower design process is to achieve a viable project where all major project components are optimised. Figures 1 and 2 showing an example design and further information on the exercise can be found in (Harrison *et al.* 2007).

3.2 Potable water supply design

This is perhaps best described by an extract from the design brief supplied to students: “As a result of pressure for new housing, it has been decided to open up a hilly area on the edge of the town of North Kilbride for development. This requires the upgrading of water supply. It has been decided to construct a new water treatment facility to replace the existing supply to a population of 30,000 and provide for 4,000 new homes... It is further proposed to refurbish and use the existing Buzzardland reservoir... originally constructed to provide water and power to serve a previous local mining activity. A survey of the area has been carried out, including an

assessment of the earth dam. No construction records exist for this, but it appears to be stable, and has been so for over 100 years. Location plan and site details are provided. You are required to achieve a design solution for the supply of treated water to the existing and new developments. You are further required to design electricity substations for the provision of domestic and industrial power to the area of new development. Upgraded supply of water and power to the village of Buzzardland, population 650, should also be included. Note that it will be necessary to take account of the Buzzardland Muir Site of Special Scientific Interest (SSSI) in any design proposals. A waste water treatment works of sufficient capacity is available on the opposite side of the town.”

This exercise involved estimating the quantity of potable water to be supplied, the reliable yield of the catchment and an analysis of 10 years of raw water quality data to determine the processes needed to produce potable quality water. It required options to be assessed for raw water abstraction and delivery, processes for treating water to a potable standard and the resultant waste, treated water delivery and waste disposal taking into account whole life costs, environmental impact, sustainability and health and safety. The output was the selected design, with detailed costs and construction schedule. These reports cover a wide range of engineering topics plus the non-technical areas essential for completion of a project of this type such as health and safety, sustainability, environmental risk assessment, and social issues.

3.3 Miniature accelerometer design

The newly emergent MEMS (Micro-Electro-Mechanical-Systems) and micro-systems technologies are inherently multi-disciplinary requiring co-ordination between physicists, chemists, material scientists, and process engineers to establish micro-machining fabrication processes as well as multi-disciplined teams of mechanical, electrical and electronics engineers to exploit the technology to realise sophisticated micro devices and systems.

This group design exercise challenged mechanical, electrical, electronic and chemical engineers to design, in detail, an accelerometer (a miniature vibration measurement instrument), which could be incorporated into an engine or pump diagnostic system. The overall aim was for each multi-disciplinary group to put forward a convincing system solution that satisfies a realistic list of performance, environmental and

operational specifications. The exercise was embellished further to include thermal management and fluidic aspects to increase the engagement of chemical engineers (Table 1) by specifying challenging environmental operating conditions, such as “the instrument must be able to measure vibrations on hot (250°C) engine blocks”. Each group was required to design the MEMS component (against a standard MEMS fabrication process) along with the associated readout and conditioning electronics. Other subsystem aspects such as packaging and thermal management needed to be considered before a convincing full microsystem solution could be proposed.

The exercise ran as a contract design project with the VP acting as the customer and multidisciplinary teams of engineers acting as design consultants. In real industrial situations, the “customer” will always want to be kept up-to-date with progress therefore, in addition to the usual project output (final report), each team was required to prepare or organise interim progress reports, presentations, telephone and videoconferencing sessions. As well as acting the role of “customer”, the VP also supported and advised the teams as required.

At the beginning of the exercise, students have little or no prior experience of MEMS technology, however their knowledge and confidence increases rapidly within the multi-disciplinary team environment. One example of a MEMS accelerometer design submitted by a typical group of 10 students is shown in Figure 3. The design incorporates six vibrometer plates equally placed on either side of a seismic mass, which is suspended at either end by means of two springs, disconnected from the substrate to form variable capacitors between the protruding fingers. To obtain a sufficiently high response a 3×3 vibrometer array design was implemented measuring approximately 4.5×4.5 mm. To improve the performance of this device, the plates were paired so that, as the mass is given a deflection in the working direction, the capacitive gap of one set of fingers increases while the other set decrease. This differential arrangement is often used by MEMS design experts to improve device linearity, however this technique is fraught with potential pitfalls all of which were identified and circumvented by the students, working across disciplines, to analyse the electro-mechanical coupling phenomena.

4. Group Operation and Outcomes

4.1 Group Structure and Operation

Prospective MEng students are asked to specify their preferences between the exercises, but the final allocations are made with the aim of ensuring that each group has an appropriate mix of students from relevant disciplines. These exercises rely upon interaction with others, especially in the final analysis and iteration towards the optimum design. Most groups had two students from each discipline which helped to achieve peer feedback, confidence in operation and often innovative thinking.

Groups are encouraged to organise themselves by appointing a team manager and deciding at an early stage how sub-activities are allocated and co-ordinated. The most successful groups develop a matrix type of approach to the exercises. The result is a well-balanced piece of work which develops in a comparative rather than piecemeal manner. Alternative solutions are identified at an early stage and well-argued reasons evolve for choosing their optimum solution.

Each group tends to work differently, as is the experience in industry, dependant upon individuals' experience of working outside their own discipline, and their ability to view the project as a whole. Individuals who question rather than accept what is expected of them ultimately are found to contribute more to the final system design. The exercises were designed explicitly to make the disciplines interact for these design tasks. As the exercises progress, they collaborate in the reporting and presentation and developed varying degrees of integration. By the end of the exercises, few students work solely within their own specialism. The true test of combined working is readily seen from the final reports: the better groups manage to provide a comprehensive document in which it is difficult to differentiate between the authors of the individual sections. Feedback from students (see Panels 1 and 2) indicated that, once they realised that they had to collaborate, their working relationships developed rapidly and, as time progressed, became more rewarding.

4.2 Overall Organisation

These design exercises take place within a strict ten week period from initial group selection and project definition to final presentation. Counting for a significant fraction of the final degree mark, (20 credit points out of an annual total of 120) these exercises represent a third of students' nominal semester work load, the remainder

being traditional exam-based lecture courses. The tight timeframe serves to motivate the students and provides a realistic simulation of industrial pressures. Each course website provides administration, guidance, reading lists, contacts and tutorial presentations.

One day a week when all students could, if necessary, work together was provided in each disciplines' timetable. Supporting lectures were given on this day and the VP was available for 'surgery' sessions for groups or individuals. This day also included the formal reporting sessions. With all of the VPs living away from Edinburgh the students were also introduced to progress meetings conducted by webcam and teleconference, see Panel 3 comments.

Groups' design freedom was inbuilt and the large variation across the final submitted system designs show that this was, to a large extent, successful. A review was provided of essential topics that are not covered in the MEng syllabi. Our experience is that the supporting lectures and notes minimise staff loading by reducing the requests for assistance. This approach mirrored the supplementary instruction of Capstone courses (Todd *et al.* 1995).

It is rare to find academics or industrialists who are technically competent to support students across three or more disciplines. However, we identified a small number of staff, able to handle the deeper system-wide queries, to provide this support.

Assessment of the work was based around a series of milestones: an initial planning document, a short mid-exercise update and a final report supplemented by an oral presentation to a multi-disciplinary panel. Marks for each of the milestones were brought together to form the group score with the final written report carrying the most weight. The majority of the marks available were based on groups' performance in evaluating the technical options open to them, their approach to integrating the design as well as their skill in design, analysis and costing of system components. The marks for individual students were calculated by combining the group mark with the outcome of a peer marking exercise that allowed students to score their colleagues (but not themselves) based on their perceived contribution to the final design. Ensuring accurate and reasonable assessment of group study projects is the subject of

ongoing investigation including the possible incorporation of student self-assessment to complement peer assessment.

4.3 Increasing Student Capability

The amount of work required from the students was significant though, in some aspects, not too technically demanding. As might be expected the work rate grew exponentially with time! Bonding was evident in almost all groups. Confidence grew rapidly in the preparation and delivery of presentations, as the exercise progressed.

The development of students' ability and comfort in handling material from outside their discipline was assessed using questionnaires at commencement and the end of the project (see Panels 1 and 2). In most cases students became more comfortable with other engineering disciplines and the use of economic information in decision-making. We noted a particular increase in the understanding between civil and mechanical engineers, reflecting the commonality between these disciplines.

4.4 Evolution and Outcomes

These design exercises are gauged as a success based on the continuing high quality of the final feasibility study reports, the oral presentations and the subsequent industrial impact. The students quickly adapted to working in a multi-disciplinary group environment and developed a selfless approach to the tasks. The technical conclusions of the design exercises, although varied, addressed all the necessary issues and were accurate in observations and results.

The issue of how to prevent students being unduly influenced by the previous years designs has been overcome in different ways. For example, the micro-systems exercise changes the instrument parameters from year to year while the hydropower exercise requires groups to devise the economically optimal scheme and attempt to 'beat' the performance of the real life scheme. An added benefit of the latter is it emphasises economics as the basis for decision-making and justification. Sustainability issues are now incorporated throughout the design exercises to further enhance the students' knowledge and skills (Nair 1998).

This is generally the first time students have been challenged on the regulatory, economic, social, and environmental context of their engineering work as required by UK-SPEC. Excellent examples of this include exposure to real-life legal, planning and

technical standards, e.g. electricity grid connection standards for small generators, as well as the environmental regulations relating to water abstraction. Also exposure to design uncertainty issues was incorporated, both through there not being unique ‘right’ answers and the challenge of designing a component part of a complex system.

Feedback from external bodies has been very positive. Accreditation visits from UK engineering institutions have specifically commended the School for their efforts in these interdisciplinary design exercises (see Panel 3). An external consulting engineer invited to the hydropower panel presentations was impressed with the degree of understanding, detail and enthusiasm in the oral reports and the accuracy of the final reports. He also thought that there was a definite link between the course and successful job prospects within the UK hydropower sector: to this end, approximately 10 employment positions were offered to the 2008 graduating class by UK renewable energy companies, giving a clear indication of the ever growing demand for renewable energy engineers. Other UK-level recognition has come in the form of a prestigious 2008 Rushlight Award for innovation with the top 2007/08 hydropower group winning the hydropower category for their “Estimator” automated design software (see Figure 4).

5. Discussion

During the operation of these exercises there have been several successful outcomes:

1. They have given the students an appreciation of other engineering disciplines.
2. Students experience working as a team, in which each member has different skills and expertise to contribute.
3. The exercises demonstrate how engineering design and economic viability are inextricably linked in designs of this type.
4. They provide an excellent opportunity to introduce students to non-technical topics (e.g., legal, sustainability, economic, regulatory) that are difficult to teach by traditional means, but are required for the degree accreditation requirements, and

5. Feedback from students (Panel 4) suggests that these exercises are enhancing students' interest in these technology sectors and also alerting students' to future career opportunities.

On the last point it is important to reiterate that the design exercises are not intended to influence future career destinations but are there to introduce interdisciplinary group working. As we do not hold graduation destination information, other than by company, we are not able to assess directly whether they do influence future career choices. The anecdotal evidence shown in Panel 4 suggests that for some students it may have the effect of making them aware of a sector or will confirm an existing interest.

It is interesting to note that several students commented that they found these design exercises every bit as stressful and demanding as examined lecture courses. Panels 1 and 2 provide extracts from the student's personal feedback on these exercises. Following several years of operation, our advice to others organising similar group design exercises is to ensure a balance in:

1. The Task: It is essential that students from each engineering discipline feel that they make a significant contribution from their own discipline.
2. The Groups: It is very desirable that each group has an approximately equal number of students from each discipline, to avoid students from a less well represented discipline becoming unduly pressurised. In the hydropower project, it was noted that the students reading the joint degree programme "Electrical and Mechanical Engineering" were highly valued for the breadth of their knowledge base.
3. The Support: It is unlikely that any academic or industrial staff member will be able to provide the necessary support for all aspects of these tasks. It is therefore necessary to involve several staff from different backgrounds, to avoid students from one discipline feeling inadequately supported.

6. Conclusions

This paper has shown how interdisciplinary design exercises can be used to improve penultimate-year MEng students' ability to operate across disciplines and improve

their preparation for transfer to industry. These exercises and the VP supervision have increased the direct industrial involvement in engineering teaching and the panels show that we have achieved several very successful outcomes: increased appreciation of other engineering disciplines; direct experience of working in multi-skilled teams; demonstration of the links between engineering design and economic viability; introduction to non-technical areas essential to the UK-SPEC; and enhancing interest in industry sectors in technological and career terms.

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9. Text Panels and Figures

Panel 1: Extracts from Student Group Comments

Learning Outcomes

“This project has allowed us to learn and develop many of the varied skills that an engineer requires, including design skills, team working skills, communication skills and report writing.”

Team working

“We have learned the importance of working together to ensure that the work being done is compatible and to ensure that no work is being duplicated. We have learned the importance of nominating a project coordinator who can oversee the entire design.”

Communications

“We have vastly improved both our verbal and written communication skills through group discussions, discussions with the client and email correspondence with the client to rest of the group to avoid misconceptions about what work is being done.”

Time management

“These skills were of paramount importance in this project. Setting interim deadlines and weekly objectives through meeting minutes, allowed us to clearly evaluate the progress of the work.”

Computing

“We increased our knowledge of different computer packages including Word, Excel and Endnote. We also had the opportunity to learn about programs not normally used in our own discipline, for example AutoCAD and Solid Edge.”

Design skills

Chemical: *“This project helped us to understand how chemical engineering can be utilised in real-life situations and expanded our knowledge of different processes used in the industry.”*

Civil: *“This project allowed us to improve on previously gained design skills and to learn new skills. We expanded our knowledge of reinforced concrete design and steel design. We also learned about designing with new materials, such as stainless steel for the acid tanks and we learned about designing new structures.”*

Mechanical: *“Taking part in the project has developed our project design skills by taking us out of our comfort zones to study material from other disciplines. In particular we have developed detailed knowledge of pump and hydraulic design.”*

Report writing

“The report writing element of this project allowed everyone in the group to improve upon their writing and computer skills. It was very important to work together. We met up to plan and write the report together and this allowed us to complete the report quicker and much more efficiently.”

Panel 2: Extracts from Individual Student Comments

Structural Engineering with Architecture

“I have a broad understanding of water treatment process from a civil/structural angle. I learned about writing up client action plans and the areas in which a client should be involved in a project. I know how to fully design a reinforced concrete liquid retaining structure. It has also allowed me to understand how to design other elements such as ground slabs, bunds and retaining walls.”

Mechanical Engineering

“From this project I have learned of the different methods available for producing drinkable water from a raw supply. I have learnt the relative merits of different forms of screening and intake structure. I have also furthered my knowledge in the factors which affect the head loss of water flow in pipe systems and networks, as well as the range of pumps available for various situations.”

Chemical Engineering

“In this project, I have learned to work with others. I have seen the effectiveness of approaching and solving problems together. I have also learned more about time management and communication with others in the group”.

Chemical Engineering

“I have learnt the importance of combining the knowledge of many different disciplines to reach a solution to a problem which spans all engineering areas. In previous group projects, which have been conducted exclusively within my discipline, little or no consideration was given to the Mechanical or Civil design”.

Civil Engineering

“From all the design work and layouts constructed the primary thing I have learned is that design work is an iterative process. By performing detailed designs of the

service reservoir I have gained knowledge in flat slab design, and concrete column design. I also learned how to design thin walled structures and members”.

Civil and Environmental Engineering

“I have increased my knowledge of concrete slab and column design and, by validating other member’s designs, I have learnt about circular design of concrete members and foundations, I have increased my knowledge of steel design and learnt how to use Excel to aid my design work for steel and concrete. I now have a significant amount of knowledge on construction scheduling, including production of accurate Gantt Charts in Microsoft Project”.

Panel 3: Extracts from Engineering Accreditation visit reports

IEE 2005: *“The multidisciplinary MEng group project, which is supported by RAE visiting professors, was also highlighted as an example of good practice.”*

Joint Board of Moderators 2006 (Civil and Structural): *“The current students described the interdisciplinary group design project as the most interesting coursework that they had done. They appeared to relish the challenges that the interdisciplinary nature brought to the project and it was clear - not least from talking to recent graduates - that the School has continued to improve this part of the degree programmes. ... The Team commended the School on the very good interdisciplinary projects and was particularly pleased to see that exposing the students to working with other disciplines was not achieved at the expense of exposure to in-depth civil engineering problems.”*

IMechE 2008: *“The panel noted that students on the renewable programmes are typically allocated the hydropower topic with approximately 60 students, grouped into 10’s and is run by visiting professor, who attends once a week. The visiting panel commended the fact that the multidisciplinary projects really were multidisciplinary and noted that the level of work seen in the projects was impressive; a reflection of this is that recently a student was encouraged to take their project idea to a manufacturing and commercial level.*

The interdisciplinary projects are a good vehicle to develop their communication skills to work across various sectors and to get a good opportunity to deal with technical uncertainty. Cost drivers are addressed and it highlights a good opportunity to manage their data and how students will cope with their projects.

A range of VPs input to these projects; in an advisory role. The ‘Belbin model’ is used to select teams and to give an understanding of group dynamics. Peer assessment is applied formulaically and then the visiting professor reviews the outcomes, this is used against a marking matrix focusing on contribution to the project where allocation of marks is awarded. Staff meet with students for 3 hour meetings each week and have a good grasp on how the students are coping and their input to and attendance at group work sessions.”

Panel 4: Comments relating to student career choices

MEMS: *“The design exercise gave me an insight into a completely new field of engineering. I found that the work allowed me to apply both my mechanical and electrical engineering knowledge together in a single project, making QinetiQ an attractive placement opportunity as a company where both disciplines were integrated. The six months spent with QinetiQ helped identify the different engineering problems associated with MEMS technology and gave me the opportunity to realise which of these interested me the most. I have now undertaken an MEng individual project closely linked to some of the work on my placement and I am now currently searching for graduate jobs in the MEMS sector.”*

Hydropower: *“I was in the hydropower stream of the interdisciplinary design project in 2005. The project had a direct influence on my career path; I gained an interest in hydropower and subsequently joined [Kendal-based] turbine manufacturer Gilbert Gilkes and Gordon Ltd for an industrial placement. Following graduation, I went to New Zealand and joined a smaller, younger company called HydroWorks Ltd who also specialised in turbomachinery design and manufacture... I returned to Edinburgh after two years to follow up my growing interest in computational fluid dynamics, but I am indebted to the interdisciplinary project for introducing hydropower as an interesting and important renewable resource. I maintain contact with Gilkes and HydroWorks and hope to work with the hydropower industry again in future.”*

Hydropower: *“The hydropower project felt real, as if we were a team of engineers with a problem to solve and some money to make. The learning curves were steeper than we were accustomed to, but this was a good thing. The opportunity to work with other engineering disciplines to solve the problem from the physics to the finances exposed us to the specialities of each discipline and gave us valuable insight into the work relationships found in industry. The financial implications of each decision was almost an overwhelming concept even for the proven technology of hydropower... There has been a natural drive [for me] to take this learning and apply it to the other renewable sectors.”*

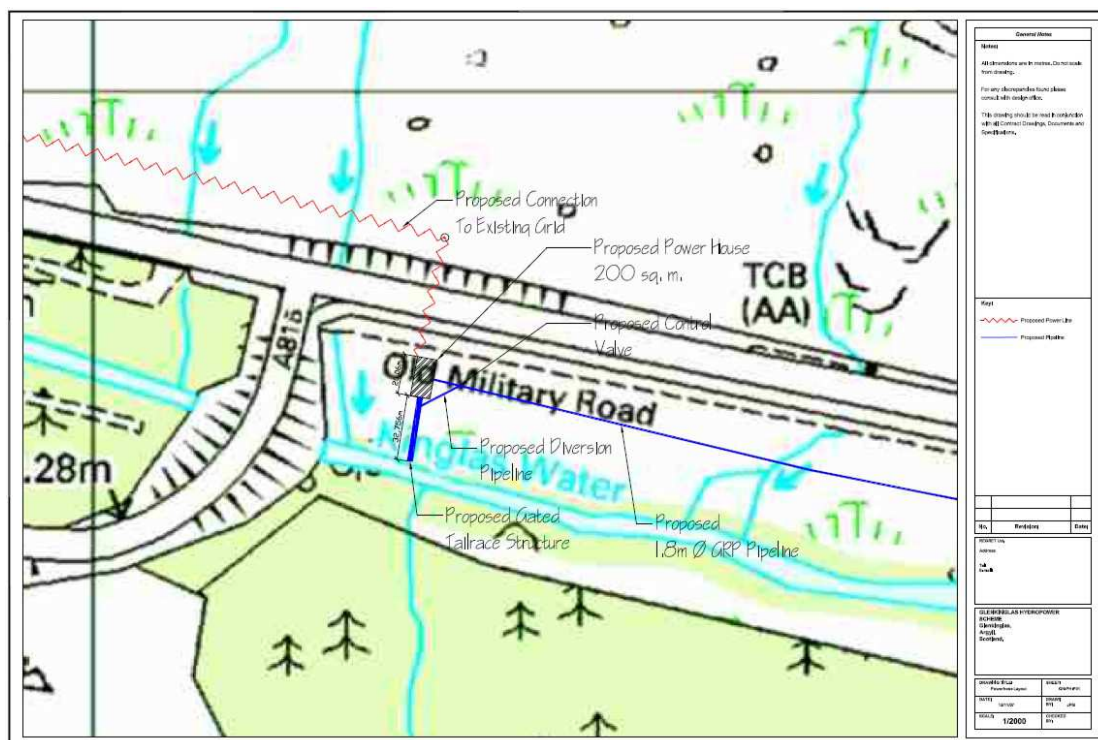


Figure 1 Location map detailing location of pipelines, electricity network and hydropower powerhouse.

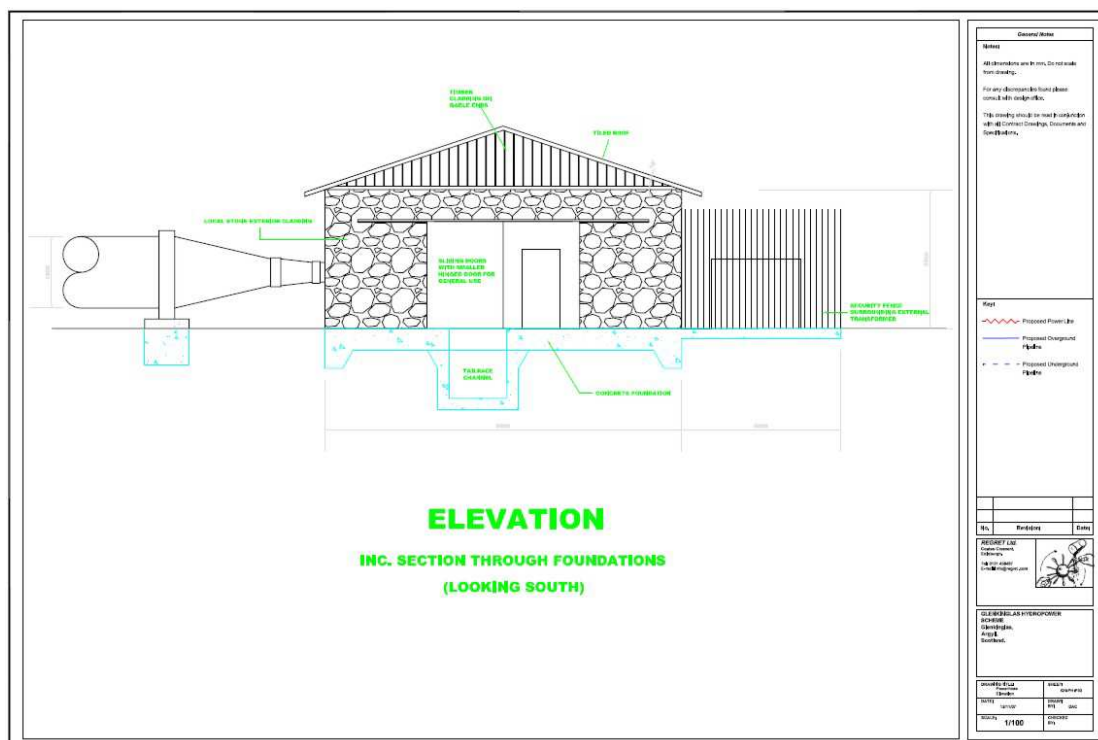


Figure 2 Example elevation of hydro scheme powerhouse.

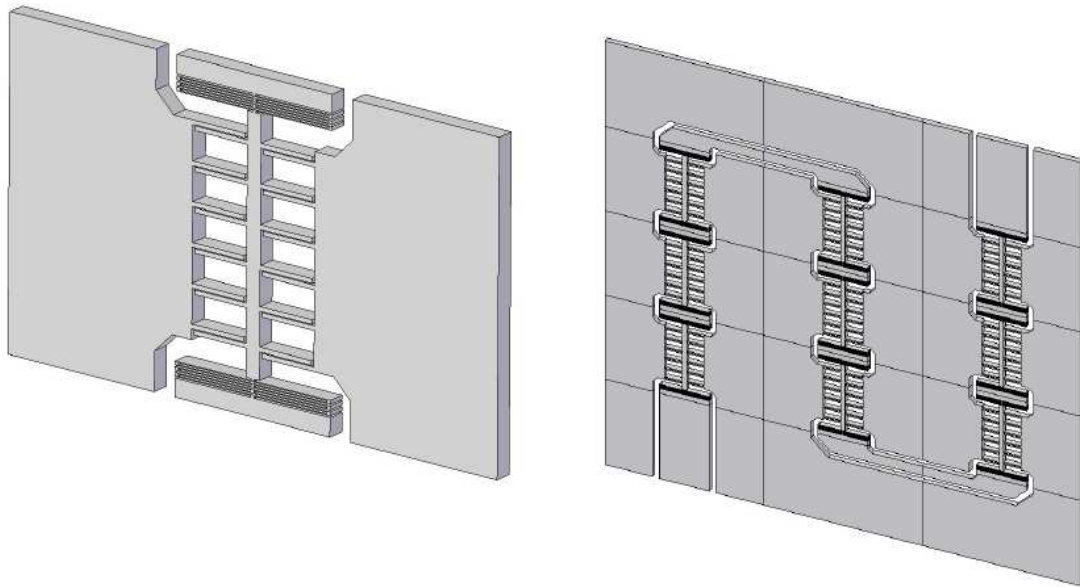


Figure 3 Single vibrometer design and a nine component vibrometer array



Figure 4 University of Edinburgh undergraduate Jeffrey Steynor receiving the 2008 Rushlight Hydropower Award on behalf of his project group.

9. Contact details

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